ITIC-IM

Version 1.0

Intermodal Transportation
and
Inventory Cost Model

Highway-to-Rail Intermodal

User's Manual

U.S. Department of Transportation
Federal Railroad Administration

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Introduction

The Intermodal Transportation and Inventory Cost Model

The Intermodal Transportation and Inventory Cost (ITIC) Model is a personal computer model for performing policy analysis of issues concerning longhaul freight movement, such as modal diversion or the assessment of economic benefits associated with changes in transportation policy or infrastructure. The model replicates the decision-making tradeoffs made by a logistics manager in selecting the mode and shipment size used to resupply his company's inventory of a particular product. The implications of making alternative choices are assessed in both modal choice and in dollars and cents terms.

Purpose and Use of the Model

The ITIC Model was developed to compute estimates of the diversion potential generated by a change in the transportation levels of service or price that would likely be caused by improvements in transportation infrastructure, transportation operations, or government policy. It can also be used to calculate estimates of the economic benefits associated with such a change. To perform this analysis, the ITIC model is used as a disaggregate demand model. The model chooses one of the transportation alternatives available on the basis of minimum total logistics costs. This is then repeated for each of a large number of disaggregate observations from a representative sample of shipper movements. Statistics can then be computed on the resulting choices and the mode and shipment size shares determined for the sample as a whole, or for any sub-sample of interest.

The model was first developed in 1995 under a joint effort by the USDOT Office of the Secretary (OST), the Federal Railroad Administration (FRA), the Federal Highway Administration (FHWA), and the Bureau of Transportation Statistics (BTS).[1] The model has undergone improvement over the past ten years, but has remained in continuous use since its development. The version described here is a slight modification of the coding of the model used in the U.S. Department of Transportation's *Comprehensive Truck Size and Weight Study (CTS&W Study)*, which was submitted to Congress in 2000.[2] That model was set up to examine the logistics costs and benefits of a series of potential highway vehicles with various axle configurations, numbers and lengths of trailers, weight limits, and tire footprints, ranging from Turnpike Doubles to various combination vehicles including Turner vehicles and Triple Trailers.[3] The ITIC model was used in this study to estimate traffic diversion from existing truck configurations to these potential vehicles, and to estimate the diversion of railroad traffic to the same potential vehicle configurations. Most of these vehicles are not currently legal on Federal highways. However, the model framework and the data developed for use in this study, is useful for ongoing policy

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[1] Transmode Consultants, Inc., *Truck-Rail, Rail-Truck Diversion Model: User Manual*, developed for the U.S. Department of Transportation, Federal Railroad Administration, Washington, D.C. 1995.

[2] The current version, the *Intermodal Transportation and Inventory Cost Model* (ITIC) was coded by Gene E. Tyworth of Pennsylvania State University, Karen White of FHWA, and Carina Tornow of Battalle, Inc. in 1998. Revisions to the model to accommodate truck-to-rail intermodal diversions were made by FRA in 2003. Simplifications to the run model were made by FHWA and FRA in late 2004 and early 2005.

[3] The highway vehicles include three trucks with semi-trailers (designated by 3 for the number of axles on the tractor, S for semi-trailer, followed by the number of axles on the trailer), two Rocky Mountain Doubles (designated RMD, followed by S and the number of axles), and three triple trailer combinations (designated by TPD and the number of axles).

studies, whether or not they involve exotic new vehicle types. The ITIC model addresses that need.

The specific application of the ITIC model addressed in this Users Manual is an estimation of diversion of highway freight traffic to rail intermodal service. However, the manual will describe how the current ITIC model can be used to develop the information needed for policy assessment involving both rail to truck and truck to rail diversion, with a single highway vehicle type—a conventional 5-axle tractor trailer combination—in a dry van equipment configuration. The model, available from the Department of Transportation's Federal Railroad Administration on a compact disk, must be used in conjunction with an appropriate set of input data of typical freight movements prepared by the user in the format explained in this user's manual.[4]

Quick Start

This version of the Department's Intermodal Transportation and Inventory Cost (ITIC) Model is for policy analysis to measure the potential for diverting highway truck movements to rail intermodal service. The model runs off of truck flow data inputs and can determine if rail intermodal can capture traffic from the ubiquitous 5-axle tractor-trailer following, for example, rail service improvements that lower shipper/receiver logistics costs. Such improvements can make rail the more efficient provider and can be tested in the model.

The following is a detailed discussion and overview of the model structure and components. To operate the model from step by step instructions and examples, go to Quick Start: Examples for Running Model on page 32.

The ITIC Model Write-up

The ITIC Model is based upon theoretical and empirical foundations that are increasingly documented and understood. It has a history of development that has stretched over more than thirty years.[5] It has been used in dozens of policy studies by both government and the private sector examining changes in infrastructure, transportation operations, pricing policy, government policy and possible advances in technology. It will be useful therefore, to describe the underlying economic theory which serves as the theoretical basis for the model, the diversion model itself, the model components and organizational structure, the databases used as input, the processes which are used to prepare the data, and finally, the steps that are followed in using the model. This write-up consists of several major sections. These include:

- An overview of the model
- Steps in performing a policy analysis
- Developing inputs for diversion analysis
- Steps in using the ITIC model
- Steps involved in making a model run

This manual also includes additional information, as well as program listings and descriptions of the material on the CD Rom.

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[4] In addition, FRA will provide on compact disc the following data sets: 1) a look up table of county to county highway miles and rail miles, 2) dray miles to/from rail intermodal terminals closest to county centroids of origin and destination, and 3) 2-digit STCC truck commodity values and densities.

[5] Roberts, Paul O., and J.R. Ginn, Stockout Costs in Inventory Management, Harvard Business School Working Paper, 71-9, April, 1971.

An Overview of the Model

The ITIC Model consists of several components including a mode-choice, shipment size diversion element, and the required level of service relationships that produce the inputs needed to allow the diversion model to function, as well as some equipment characteristics tables and other tables that allow the user to set out the parameters of a particular scenario. The model was designed from the outset as a discrete choice model for use in conjunction with disaggregate freight movement databases. It has a long history of development and use coming out of the extensive work on transportation demand models done in the 1970s.

The approach used in the ITIC freight diversion model is based on an earlier mainframe model—the Translog Shipper Cost Model—developed by a research team at the Massachusetts Institute of Technology (MIT) Center for Transportation Studies,[6] which has served as the conceptual design for later models. The most notable of these is the Intermodal Competitive Model (ICM) employed by the Association of American Railroads for analyses of policy issues of significance to the railroad industry. As mentioned previously, the first version of the model developed for use on a personal computer spreadsheet was the Truck-Rail, Rail-Truck (T/RR/T) Diversion Model developed for the Department of Transportation by Transmode Consultants, Inc.[7] That version of the model was the first to include a module for diversion from truck-to-rail. The ITIC Model is an outgrowth of an updated and expanded version of the T/RR/T model prepared for FHWA by Science Applications International Corporation in 1998[8] with extensive updates by FHWA and FRA. The current version of the ITIC model has been recoded to simplify the inputs needed for the many size and weight scenarios examined by the Department in the Comprehensive Truck Size and Weight Study prepared for Congress, and to review and refine some of the inputs and logistics cost functions in the model.[9]

This overview will present the theoretical basis for the model, a description of the conceptual framework within which the model system resides, and a brief review of the functioning of the Logistics Cost Module. The balance of the chapter will be devoted to a description of how the model is used in policy analysis.

Basic Nature of the Model

Travel demand modeling has been the subject of considerable research since the 1950's when the development of electronic computers made it possible to use them in transportation planning studies. The first models were aggregate models dealing with passenger transportation. More recent models, including this one, are disaggregate models. This point deserves further explanation.

The rise in urban transportation planning prompted by the Interstate Highway Program, along with the emergence of the electronic computer and its increased ability to handle large quantities of information led in the early 1960s to the development of computer models for estimating passenger travel demand. Most of these early travel demand models were "aggregate" models, dealing primarily with passenger travel. Aggregate models of personal travel predict the behavior of an aggregation over travel zones of single individuals facing an average set of travel conditions. In perhaps the most well known aggregate demand model—the gravity

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[6] Roberts, Paul O., *The Translog Shipper Cost Model*, MIT Center for Transportation Studies Report No. 81-1, developed under a U.S. Department of Transportation University Research Program contract, Cambridge Massachusetts, June, 1981.

[7] *Truck-Rail, Rail-Truck Diversion Model*, Op. Cit., 1994.

[8] Science Applications International Corporation, Transportation Consulting Division, *The Logistics Cost Model Write-up*, McLean, Virginia, January, 1997.

[9] See footnote 2.

model—travel between zones is computed to be directly proportional to the number of trips originated in each origin zone and terminated in each destination zone, and inversely proportional to the square of the distance between the two zones. The problem with an aggregate model is that it is not "zones" that travel, but people and freight. The differences between travelers within the zone (over such characteristics as auto ownership, income, age, family size, etc.) may be more important in determining the propensity to travel than the distance between zones. Segregating travelers within the zone into more or less homogeneous groups and treating each group separately can help the analyst deal with this problem. As more and more determinants of demand are identified, more and more groups are needed to properly represent them. In the extreme, each travel unit would be treated individually. This leads to a disaggregate model.

Disaggregate models use the characteristics of the travel unit and the characteristics of the alternatives available to determine how the trip of a single individual will be made. A separate result is obtained for each individual as a function of the variables identified in the model. A disaggregate approach is even more important for freight than for passengers since the annual usage of products can range over several orders of magnitude. A product used at a rate of 10 pounds per year and a product used at a million pounds per year have a difference in use of 5 orders of magnitude. They require totally different treatment, have completely different logistics costs, and typically select different shipment sizes, and even different modes. Product value and shelf life are also extremely important to modal selection. High product value influences the amount of inventory that it is economical to hold, as does a short shelf life.

In order to take these factors into account one must approach the forecast from the point of view of the individual decision maker, in this case, the individual shipper or receiver. This logistics decision maker must balance the low cost per unit of making a large shipment against the cost of carrying this product in inventory until it is used up—or the higher unit cost of making a smaller shipment against a lower inventory cost, but a higher cost for more frequent reordering. Using an aggregate model completely ignores this tradeoff and risks forecasting a totally incorrect set of choices. Consequently, it is important to use a "disaggregate" forecasting approach rather than an "aggregate" methodology that may not be typical of any single decision maker.

The good news is that it is possible to use the behavior of the individual decision maker as the economic rationale underlying the model. This computation is typically performed on the individual observations in a stratified random sample of freight movements in the area of interest. In such a sample, each observation carries an expansion factor that indicates the number of movements that this observation represents in the real world. The final answer is developed by summing the result over the sample as a whole.

The principal virtue of using a disaggregate sample is that all of the richness of the original sample is preserved rather than being lost as a consequence of aggregation, as it would be in an aggregate model. One can perform cross tabulations on the output of the model to determine aggregate statistics on the number of trips by type of shipper/receiver, type of conveyance chosen, characteristics of the move, location, distance, trip time, cost, or any one of the many other variables typically available in the original data set. Type of commodity can be viewed at the 2-digit STCC code level, at the 5-digit level, or anywhere in between. Where policy analysis is likely to involve any one of dozens of different variables or subtle relationships between variables, disaggregate models are of unusual utility.

Theoretical Basis for the Model

Economic theory treats transportation just like any other factor used in production. The problem is that it is different, not only in terms of its nature, but also in terms of its impact on each of the other inputs. The theory of the firm is based on the assumption that each firm minimizes the costs required to produce a given quantity of output. Transportation, though only one of the factors of production, is different in that it is not consumed directly, but is a service used only in processing other inputs or outputs. If transport costs are excessive, this results in higher costs for those inputs that require transport, which in turn, results in a higher cost for the delivered product.

The neoclassical approach used by economists in modeling the behavior of shippers who face competing modes is typified by the work of Friedlaender and Spady[10], who begin with the observation that truck and rail transportation are only two of many inputs used by the firm in producing its basic products. In their choice of inputs they attempt to select that set which maximizes profits, using more of one input and less of another. Transportation is then, according to the neoclassical approach, just another input. The firm values each input in terms of its marginal contribution to profits.

To implement the neoclassical approach requires information not only on the transportation expenditures made by the firm, but also on all of the other inputs, including land, labor and capital. Further, this approach requires that one know what all of the inputs into the particular industry are and how they are used in the production process. Implementing the neoclassical approach as an everyday decision analysis tool becomes unworkable without gross oversimplification. It is therefore not practical for our purposes here, though it does shed light on the manufacturing tradeoffs that are possible and the role of transportation in the process.

Other models of freight demand have been explored in the literature. In 1988, a Transportation Research Board Study of freight demand[11] summarized the models and the freight flow data that are generally available to practitioners in this field. None of these has achieved prominence for a variety of reasons, the most important of which is that many are aggregate models. Chiang[12], in his doctoral dissertation, provides an explanation of the problems that are associated with most of these aggregate models.

> "*Most of the existing freight models are correlative rather than explanatory and completely insensitive to changes in transport level-of-service measures. This is due to a number of factors; first, the data limitations. Data which can be used to undertake a careful estimation of a disaggregate behavioral freight demand model are almost nonexistent. Thus, researchers in the past have been constrained to either piecing together useful aggregate data to estimate an aggregate demand model [13] or to using shipper surveys to estimate very limited shipper choice models. [14]*
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> *A second limitation comes from the fundamental difficulties which most researchers have experienced in attempting to apply economic theories of derived demand to freight demand analysis without making unattractive simplifying assumptions. One frequently used assumption is constant transport cost. That is, the freight rate is assumed not to be influenced by the quantity shipped. This makes the model policy insensitive to changes in the transportation level-of-service. In fact, in practice freight rates are a decidedly decreasing function of shipment size. There are clearly economies to the shipper to large shipment sizes.*
>
> *Finally, the true cost of transport should include inventory costs as well as tariff charges which results from the logistics management process and are thus also a function of shipment size.*"

A second approach taken by economists and other transportation researchers is to assume that the inputs required in the production process are those already observed moving in the transport system. The traffic departments of most firms routinely record individual records

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[10] Friedlaender, A.F. and R.H. Spady, *Hedonic Rates and the Derived Demand for Freight Transportation*, Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge, MA, 1977.

[11] Jack Fawcett, Associates, *Transportation Demand Forecasting*, Transportation Research Board Special Report, 1988.

[12] Y.S. Chiang, *A Policy Sensitive Model of Freight Demand*, PhD Dissertation, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1979.

[13] Examples include, Morton (1969), Tihansky (1972), Wang and Epstein (1975) and Sloss (1971).

[14] For examples see articles in Mathematica by, Miller (1972), and in (1969), and Watson *et al.* (1974).

concerning these shipments. As Chiang points out "*It is clear that the firm is the basic decision-making unit in freight transportation."* These records kept by the firm include bills of lading, carload waybills and truck freight bills. Each is an indication of the use of a product in the production process of a manufacturer, or the distribution process of a wholesale distributor, or a retail merchandiser. Different suppliers, modes, or shipment sizes are possible alternatives to the observed movement, but the use of the product as input to the firm's production process is taken as fixed. This does not seem an unreasonable assumption over the short run.

Freight demand models of this second type have been reported on by Roberts, Chiang and Ben Akiva,[15] by Winston,[16] and by others. The philosophy underlying the diversion component of these models is that the receiver is a rational economic decision maker who attempts to minimize the total cost of acquiring the inputs he needs for production, shipping them to the place he needs them in the process, storing them until their use and protecting the company against possible shortages during the process. In short, the receiver attempts to minimize total logistics costs for the delivered product. This involves not only the selection of the mode of transport to be used, but also the selection of the supplier of the product, the choice of inventory control system, the location of warehouses and the firm's overall strategy for serving the market. The process is too complex to address in detail at this point, however, the basic theoretical foundation of the model described here is based on this concept.

Applications of This Family of Models

These findings have been incorporated into modal choice models used in a number of freight policy studies.[17] [18] One such model, the Intermodal Competitive Model,[19] has been used by the Association of American Railroads to investigate the potential diversion from rail that would occur if longer combination vehicles were allowed to operate on the Nation's Interstate Highway System. In addition to the *Comprehensive Truck Size and Weight Study* cited earlier, the U.S. Department of Transportation has used the ITIC model to assess rail-to-truck and truck-to-truck diversion in the *Western Uniformity Scenario Analysis,* a regional truck size and weight scenario requested by the Western Governors' Association.[20] SAIC has used an earlier version of the model to explore potential truck tolls levels required to support the construction of a new low-level bridge across the Rio La Plata, from Buenos Aires in Argentina to Colonia in Uruguay.[21] Other recent applications of the model are: an analysis of the potential for the construction of a new

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[15] Paul O. Roberts, Moshe Ben Akiva, M. Terziev, and Y.S. Chiang, *Development of A Policy Sensitive Model For Forecasting Freight Demand*, M.I.T. Center for Transportation Studies, CTS Report 77-11, Cambridge, MA, April 1977.

[16] Winston, Clifford, *Mode Choice in Freight Transportation*, Department of Economics, University of California, Berkeley, CA 1978.

[17] Roberts, Paul O., with Mark Terziev, James Kneafsey, Lawrence Wilson, Ralph Samuelson, Yu Sheng Chiang, and Christopher Deephouse, *Analysis of the Incremental Cost and Trade-Offs Between Energy Efficiency and Physical Distribution Effectiveness in Intercity Freight Markets*, MIT Center for Transportation Studies, Report CTS 76-14, Cambridge, MA, November, 1976.

[18] Roberts, P. O. with Tom Brigham, and Carol Miller, An Equilibrium Analysis of Selected Intercity Freight Markets: Truck with Double Trailers vs. TOFC Shuttle Trains, MIT Center for Transportation Studies Report CTS 77-25, Cambridge, MA, December, 1977.

[19] The Intermodal Competitive Model was programmed for the AAR by an outside contractor from a model design developed by Dr. Paul O. Roberts and described in "*The Translog Shipper Cost Model*" Op. Cit., 1981.

[20] FHWA, *Western Uniformity Scenario Analysis*, a study performed at the request of the Western Governors' Association, Washington, DC, 2003.

[21] *Freight Mode Split Analysis for the Buenos Aires – Colonia Bridge Feasibility Study*, prepared for Louis Berger International by SAIC Transportation Consulting Division, October 1997.

intermodal terminal in the Richmond Area,[22] use of the model to examine the impact of changing tolls on Mexican toll roads,[23] an analysis for the Canadian Transport Commission of the impact of government policy on Canadian competitiveness,[24] an analysis of the impact of changes in the hours of service by truck drivers by ICF Consultants for the FHWA,[25] FHWA's *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association,* and FRA's analysis of the economic benefits of positive train control.[26] The FRA analysis represents the first time the ITIC model was used to assess truck-to-rail intermodal diversion.

Variables Affecting Choice of Supplier, Shipment Size, and Mode

The factors influencing a shipper's choice of mode are complex and highly interdependent. They have been previously analyzed in studies conducted by researchers at MIT.[27] They involve tradeoffs between the cost of transportation and overall transit time and delivery reliability, but there are more subtle underlying factors.[28] Research reveals that the principal decisions in this mode selection process are those that affect the receiver of the goods rather than the shipper. Typically, the receiver is the buyer of goods, the shipper is the seller and the ownership of the goods is usually transferred legally at the time the shipment is loaded onto the conveyance. Thus, the shipper is typically the receiver's "agent" in the process and it is his wishes that are honored in the size of shipment and the choice of mode. It is therefore appropriate to view the process as involving a single decision-maker—the shipper/receiver.

The most important tradeoffs involve the annual use of a product by the receiver. High annual use of a product allows the receiver to order large replacement shipments and to take advantage of the low transport costs afforded by economies of scale in shipping associated with large shipment sizes.[29] High value of the product imposes a penalty to ordering more than can be readily used by tying up capital in inventory. Excess inventory can be avoided by ordering product more frequently in smaller shipment sizes. Small shipment sizes carry their own penalties. Ordering is a costly process. Smaller shipment sizes typically carry high unit cost of transportation, and if the shipment size is smaller than a full vehicle load, the load must be picked up at the origin by the freight carrier and consolidated before shipment, then deconsolidated and delivered at the destination end. Most LTL, less than truckload, trucking, parcel carriers and airfreight systems perform consolidation/deconsolidation of smaller shipments into full vehicle loads. The consolidation and deconsolidation processes are also expensive, sometimes exceeding the cost of linehaul transportation.

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[22] Reynolds, Smith and Hills, *A Study of the Feasibility of a Regional Intermodal Terminal*, performed for the Richmond International Airport and the State of Virginia, Jacksonville, Florida, 2000.

[23] Felipe Ochoa y Asociados, Estudio de Carreteras in Mexico, Mexico, D.F. 2000.

[24] Consilium Services, Inc., *Modal Integration in Support of Canada's Competitive Position in a Global Market Place*, prepared for Transport Canada, Vancouver, B.C. June, 2002.

[25] ICF, *An Analysis of the Impact of Changes in Drivers Hours of Service*, prepared for the Federal Highway Administration, McLean, VA, June, 2003.

[26] Federal Railroad Administration, *Study of The Benefits of Positive Train Control*, 2004.

[27] Roberts, Paul O. with Y.S. Chiang, *Development of a Policy Sensitive Model for Forecasting Freight Demand*, U.S. Department of Transportation, Assistant Secretary for Policy and International Affairs, DOT-P-30-81-04, Washington, D.C., March, 1981.
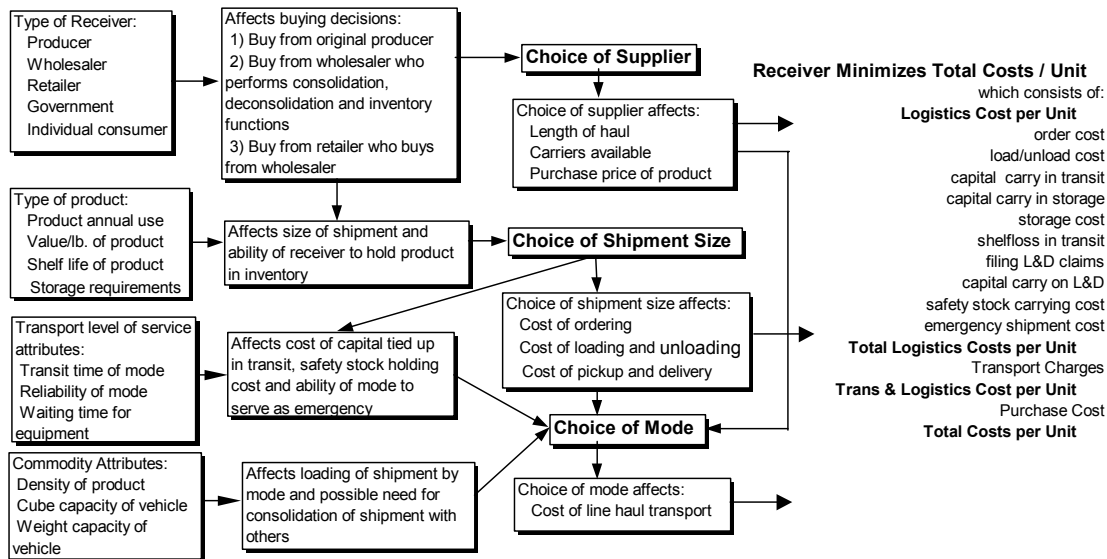
[28] Roberts, Paul O., *Factors Influencing the Demand for Freight Transport,* CTS Discussion Paper 8-75, MIT Center for Transportation Studies, Cambridge, Massachusetts, August 1975.

[29] Roberts, P.O. and A.S. Lang, *The Tradeoffs Between Railroad Rates and Service Quality*, M.I.T. Center for Transportation Studies, Report 78-12, May 1978.

Other variables can also play an important role. The density of a product influences the choice of vehicle either by loading "heavy," in which case **payload** is important, or loading "light," in which case **cube** is more important. Shelf life influences choice of mode by placing a premium on transit time, where longer travel time leads to less time available on the grocer's shelf before the product spoils. Loss and damage may lead to a need for emergency shipments. Many variables turn out to be important to the process.

The variables typically involved in the decision process are shown in the figure below. This figure shows that many of the variables interact with other variables to produce the conditions that result in the final choice of supplier, shipment size and mode.   The results contribute to the shipper/receiver's total logistics cost per unit.

Variables Affecting Choice of Supplier, Shipment Size and Mode in Freight Transportation

Type of Receiver:
   Producer
   Wholesaler
   Retailer
   Government
   Individual consumer

Affects buying decisions:
 1) Buy from original producer
 2) Buy from wholesaler who performs consolidation, deconsolidation and inventory functions
 3) Buy from retailer who buys from wholesaler

Choice of Supplier

Choice of supplier affects:
   Length of haul
   Carriers available
   Purchase price of product

Type of product:
   Product annual use
   Value/lb. of product
   Shelf life of product
    Storage requirements

Affects size of shipment and ability of receiver to hold product in inventory

Choice of Shipment Size

Choice of shipment size affects:
   Cost of ordering
   Cost of loading and unloading
   Cost of pickup and delivery

Transport level of service attributes:
 Transit time of mode
 Reliability of mode
 Waiting time for equipment

Affects cost of capital tied up in transit, safety stock holding cost and ability of mode to serve as emergency

Choice of Mode

Commodity Attributes:
 Density of product
 Cube capacity of vehicle
 Weight capacity of vehicle

Affects loading of shipment by mode and possible need for consolidation of shipment with others

Choice of mode affects:
   Cost of line haul transport

Receiver Minimizes Total Costs / Unit
which consists of:
Logistics Cost per Unit
order cost
load/unload cost
capital carry in transit
capital carry in storage
storage cost
shelfloss in transit
filing L&D claims
capital carry on L&D
safety stock carrying cost
emergency shipment cost
Total Logistics Costs per Unit
Transport Charges
Trans & Logistics Cost per Unit
Purchase Cost
Total Costs per Unit

Tradeoffs Made By The Shipper/Receiver

Most of these variables affecting the choices of the receiver have been incorporated into the ITIC Model. The program develops the tradeoffs that would be made by a receiver who is attempting to minimize the total logistics costs associated with maintaining an inventory of the product for use in manufacturing or wholesale trade. The variables are used to develop each of the individual cost factors listed on the right hand side of the figure above. They include the type of receiver, variables that describe the product, information on the current mode of transport and potential new modes and the attributes of the product being carried.

These variables are used to write equations for each of the components of the receiver's total logistics costs as a function of the principal choice variables (i.e. choice of supplier, choice of mode and choice of shipment size). Total logistics costs can be expressed in cost per unit, cost per hundredweight or annual cost. Transport charges are added to logistics costs to give the total transportation and logistics cost of the strategy.   If different suppliers are considered, with different purchase costs, the total delivered cost per unit or per hundredweight is given. Most receivers will select that strategy with the minimum total delivered cost. This program can be used to examine those circumstances under which one mode will be chosen over other modes.

Truck-to-truck diversion involves decisions made by carrier management as to what equipment to use to accomplish a particular movement. By contrast, rail-to-truck, or truck-to-rail diversion involves a decision by the shipper/receiver to use another entirely different mode of transport. This "between modes" type of decision is more complex, involving the evaluation of

tradeoffs in equipment availability, transit time and reliability of delivery, freight loss and damage experience and the size of the potential shipment and its suitability for movement on the mode in question. The shipper's rationale for making these decisions must be modeled if these tradeoffs are to be evaluated properly.

Cost of Movement to the Receiver

In the model, the person responsible for making the modal decision can be viewed as attempting to select that mode and shipment size which for a particular origin to destination movement will minimize the total logistics cost of the goods being shipped to the receiver. Demand for transportation service by a particular mode may grow or shrink in response to changes in service or cost, depending on its impact on the individual shippers' own business and the other alternatives available. However, the model assumes that all of the product used annually will move by one of the alternatives.

In the model these key variables may be grouped into three major groups:

1. Shipper/receiver attributes
2. Commodity attributes
3. Transport attributes

As described earlier, the most important variable appears to be one of the shipper/receiver attributes, the annual use of the product by the receiver. Clearly, rail as a mode is uniquely capable of handling larger individual shipments than truck. The typical carload can handle shipment weights up to 200,000 pounds, or more, while a maximum single unit truckload payload is around 50,000 pounds. Rail carload shipments of 100 tons are routine and multicar shipments of 1,200 tons or more can be handled on the same bill of lading. Unit trains moving as much as 10,000 tons (20 million pounds) are also common. By contrast, if a shipper must take a 200,000-pound shipment in order to use rail, instead of the 20,000-pound shipment he would like to take, it could result in thousands of dollars of unwanted inventory cost. Shipper modal choice behavior, then, depends importantly on the amount of product used annually.

Commodity attributes are also important determinants of shipper behavior. The product being shipped determines the loading and handling requirements as well as the maximum size of shipment that can be accommodated in a given piece of equipment. These variables include:

- density
- value per pound
- shelf life
- typical packaging

Some of these data are available in a Commodity Attribute File from the Federal Railroad Administration. The relevant product data are appended to the individual movement observation in the input data prepared by the user for input into the model.

Variables describing transport attributes of the modes under consideration have also proven to be important. These include

- availability of equipment
- transit time
- reliability
- loss and damage experience

These and other variables are incorporated into a "shipper's utility function" within the model. Models for estimating level of services attributes are included in the ITIC model as well as earlier versions of the model.[30] The obvious choice for the shipper's utility function is the "total

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[30] Paul O. Roberts "Predicting Freight Transport Level of Service Attributes", Co-authored with Kung Wang, M.I.T. Center for Transportation Studies, CTS Report 79-17, Cambridge, Massachusetts, December 1979.

logistics cost" associated with the ordering, transport, inventory and use of the product being shipped. Total logistics cost is the item that the shipper is attempting to minimize when he selects one mode of transportation over another or one shipment size over another. This approach has been employed in numerous studies of rail-to-truck diversion over the last several years. Similar versions of the model have been used in litigation support before the Interstate Commerce Commission (ICC)[31] [32] and the Canadian Transport Commission (CTS)[33] as well as in marketing studies for a number of freight carriers, both truck and rail and for product distribution companies[34].

The components included in the shipper's total logistics cost function include:

- ordering cost
- capital carrying cost in transit
- capital carrying cost in inventory
- warehousing cost
- loading and unloading cost
- safety stock carrying cost
- cost of loss and damage claims

These variables (along with a few parameters and descriptive variables) allow the total logistics costs of acquiring, shipping and storing the product to be computed by the model.

The Special Importance of Reliability

Special attention needs to be given to the reliability of the lead-time associated with the restocking of a product used on a continuous basis. Reliability has already been identified as one of the principal variables that affect the choice of mode and shipment size. Reliability as defined here is the variability in the ordering lead-time. Lead-time includes the time required for the shipper to receive the order from the user, pick the order from his inventory, arrange for carriage, wait for a vehicle to arrive at the shipping dock, load the shipment, and finally, to travel from the shipping point to the final destination. Reliability is important primarily because it impacts the amount of safety stock that needs to be carried to insure that the user does not run out of the item. Safety stock is typically a larger component of total logistics cost than many of the other costs (with the possible exception of transportation charges) because it must be carried continuously. If the user must break into the safety stock to avoid a stockout, he must replace it immediately, or place the operation into jeopardy of a stockout the next time he reorders.

At the time that the order is placed, there is uncertainty as to exactly when the shipment will arrive—more with some modes than with others. There is also variability in the use rate that may exacerbate the uncertainty that current stocks will last until the shipment arrives. As a

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[31] Verified Statement of Dr. Paul O. Roberts Before the Interstate Commerce Commission", Docket No. 40266, Application for Permission to Merge the Assets of the Burlington Northern Railroad and the Atchison, Topeka and Santa Fe Railroad, September 1994.

[32] "Verified Statement of Paul O. Roberts Before the Interstate Commerce Commission", Docket No. 12345, Application for Permission to Merge the Assets of the Union Pacific Railroad and the Southern Pacific Transportation Company, November 1995.

[33] *Truck-Rail Competition in Canada*, a consulting report summarizing the findings concerning the impact of consolidating CN and CP in the east prepared for the management of the Canadian National Railroad by the SAIC Transportation Consulting Division, Mclean, Virginia, November, 1996.

[34] "The Network Planning Model Review of Logistics Strategies for ProSource Distribution Services", a consulting report prepared by SAIC Transportation Consulting Division and Harvey Consultants, Inc., Mclean, Virginia, November 1996.

consequence, in our analysis and accounting of reliability in the ITIC model, we must view the arrival of a particular shipment as a probability distribution of arrivals at various points in time. For shipment by truck, the arrival is fairly predictable. Other modes, particularly rail carload, are not as reliable. In fact, rail carload is typically skewed to the right with a long tail to the distribution. A distribution that works well to represent this phenomenon is the Gamma distribution. Unlike the Normal distribution, the Gamma distribution can be made to have a tail that extends to the right.

The Gamma distribution has two parameters, Alpha and Beta, which shape the distribution. The equation for the Gamma distribution is:

$$F(x; Alpha, Beta) = (1/(Beta^{Alpha}*Tau(Alpha))*x^{(Alpha-1)}*e^{(-x/Beta)}$$

By specifying Alpha and Beta, one can cause the distribution to be peaked with a small tail to the right, or flatter with a long tail to the right.

Gamma Function w/ Various A & B
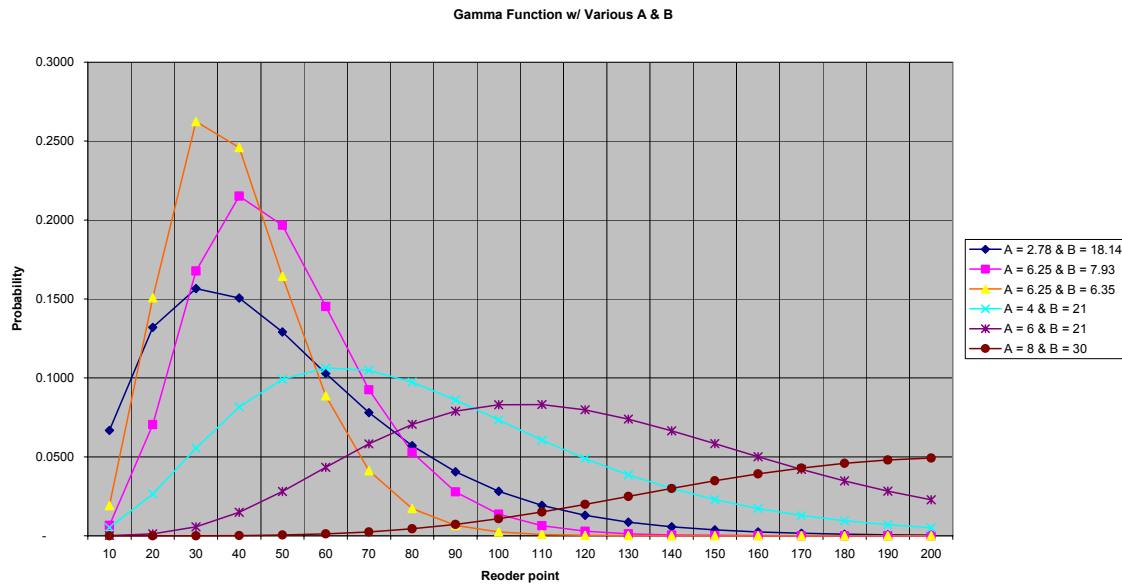
The ITIC model has been designed to define Alpha and Beta as functions of the mean and the standard deviation of the shipment transit time only. The purpose here is to estimate the effect of transport reliability of the modes on required safety stock—not the effect of variation in demand for the receiver's product. The mean transit time here is the shipper's mean lead-time for reordering. The calculation does not reflect variation in the receiver's daily use of the product. Rather, the daily use rate is assumed to be constant at the annual average daily use. Given Alpha and Beta, the Gamma distribution gives the amount of product used during the reorder period for each point on the Gamma probability distribution.[35] Using the inverse of the Gamma function allows one to specify the probability one wants to use for the corresponding reorder point. One needs only to compute Alpha and Beta from the mean daily use of the product and its variability (measured in this case by the standard deviation of the transit time) and specify the point on the curve beyond which the shipper feels adequately protected (90%, 95%, 98%, etc.). Then, the inverse Gamma distribution function is used to compute the reorder point.

The formula for Alpha is:

Alpha = (mean use during lead time)^2/(std dev use during lead time)^2

The formula for Beta is:

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[35] See Tyworth, J.E., Guo, Y., & Ganeshan, R. "Inventory Control Under Gamma Demand and Random Lead Time," *Journal of Business Logistics* (1996), 17(1), 291-304

Beta = (std dev use during lead time)^2/(mean use during lead time)

With Alpha and Beta defined, the reorder point is computed using the inverse Gamma function found in Excel:

Reorder point (tons) = GAMMAINV(% protection, Alpha, Beta)

From the reorder point the amount of safety stock that must be held to provide the specified % protection is:

Safety Stock (tons) = (reorder point – mean demand during lead-time)*2000

These computations are performed in the ITIC model in a separate section of the TSW spreadsheet. To control reliability of the various modes in the model, a single parameter, the coefficient of variation (COV) of *transit time* (mean ordering lead-time), is specified by the user on the Assumptions Sheet. COV of transit time is defined in the model as the standard deviation of transit time divided by the mean transit time. A value for the COV greater than 0.5 indicates a function in which the tail of the distribution is clearly skewed to the right. A value of less than 0.5 is associated with a function shaped more like a normal distribution. A value of 1.0 creates a function skewed to the left like an exponential function. Values of 0.45 for TOFC and 0.40 for truck have been assumed in the runs of the model used here.[36] These parameters produce distributions that appear to be representative of the relative reliabilities of the different modes.

The COV of transit time, i.e., reliability is used to calculate the standard deviation of lead-time (calculated as mean lead-time multiplied by the coefficient of variation). The Alpha and Beta parameters are developed using both the mean daily use rate and COV of transit time during lead-time. The Alpha and Beta parameters are then used to define the Gamma distribution used in the computation of safety stock and the required days of protection. Note that the cost of a stockout, should it occur, must be balanced against the cost of carrying the extra safety stock as protection. An example of the computation is shown in the table below.

Safety Stock /Reliability Calculations

Shipper/Commodity Characteristics

lb/day	32,877		
$/lb	$0.51		
required protection (service) level	95%		
inventory carrying cost factor	30%		
dray miles 62 rail miles 1164	3-S2 truck miles	974	

Modal Performance	TOFC	3-S2 Truck
wait time	0.50	0.50
Transit time (includes TOFC 1 day dwell)	2.70	1.95
Assumptions Row 8		
coefficient of variation of lead time	0.45	0.40

Safety Stock Calculations	TOFC	3-S2
mean lead time	3.20	2.45
std. deviation of lead time	1.44	0.98
coefficient of variation of lead time	0.45	0.40
mean use during lead time (tons)	52.60	40.27
std. dev. of use during lead time (tons)	23.67	16.11
alpha	4.94	6.25
beta	10.65	6.44
reorder point (tons)	96.60	69.90
safety stock (lb)	87,989	59,256
required days of protection	2.68	1.80

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[36] While these are the default values, FRA and FHWA are continuing to evaluate the accuracy of them. Only the difference in truck and intermodal COV is relevant for mode choice in the model; however, the "size" of the COV affects the amount of safety stock, and therefore total logistics cost. In the meantime, the user can, of course, adjust these as appropriate. We invite any comment or analysis concerning the suitability of these measures here.
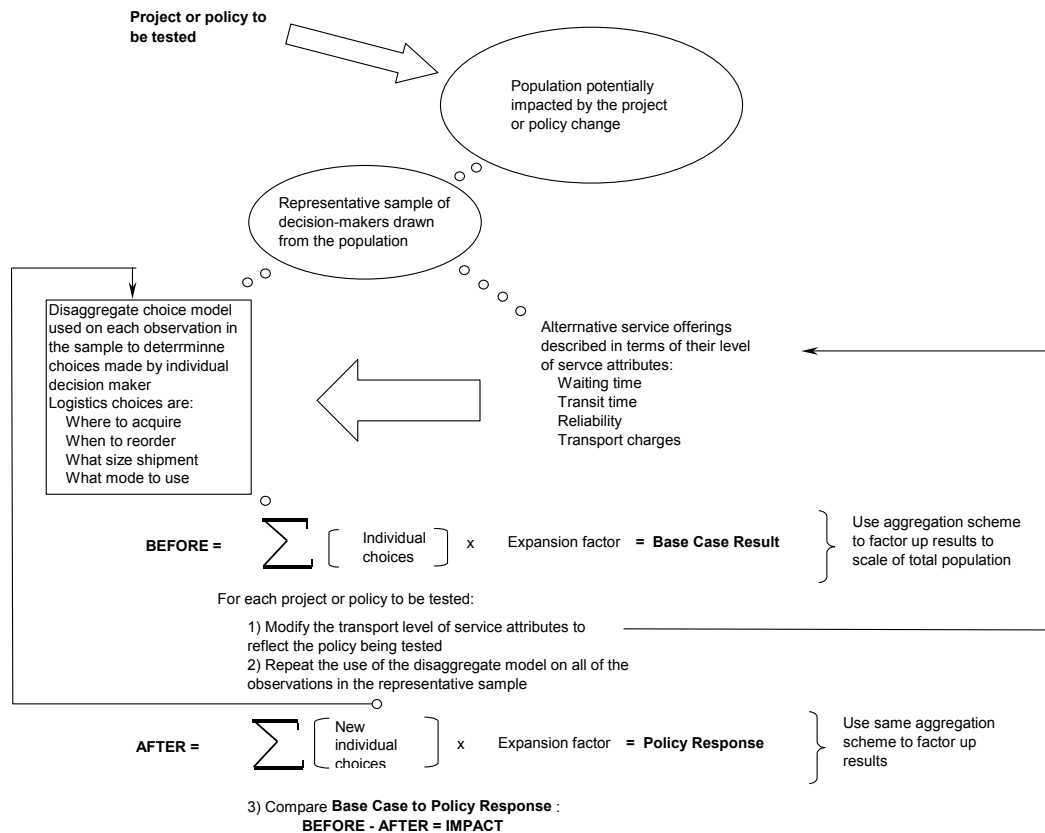
Two plots showing the Gamma distribution probability representing the lead-time situation for TOFC and Truck in the table above is presented below.

Probability that Shipment Arrives in T Days
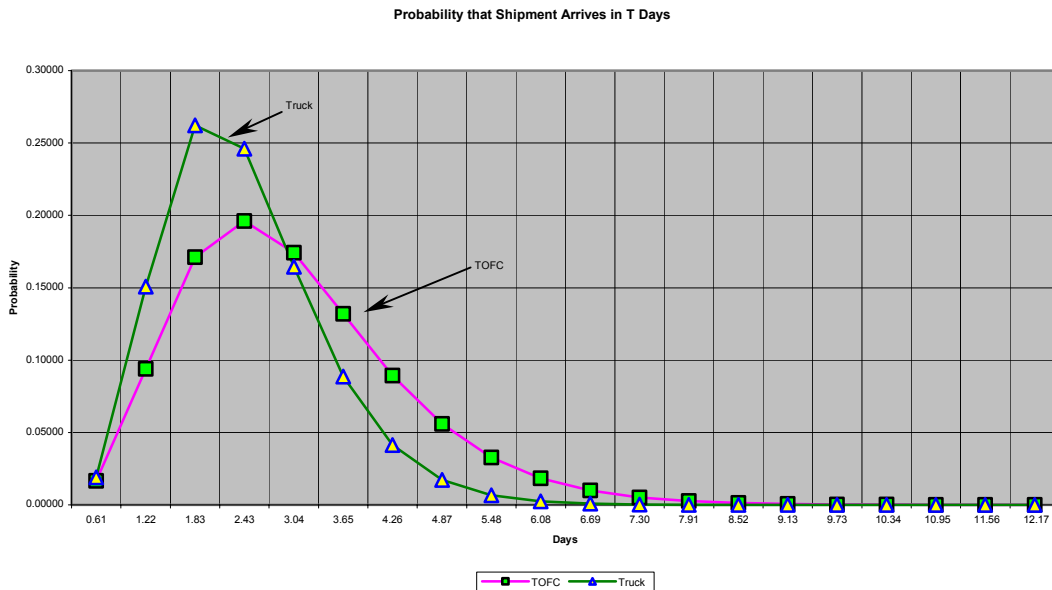
All of the elements of the reliability computation have been programmed into the ITIC model. The user needs only specify the % protection, the transit time and the coefficient of variation from which the standard deviation of transit time is computed. (While these parameters can be easily changed, default values are already incorporated into the model on the Assumptions Sheet, which will be discussed in more detail below.) The model then develops the appropriate probability distributions from which a safe reorder point for the user is then calculated.

How the Model Can Be Used For Policy Analysis

Using the ITIC model in policy analysis is conceptually straightforward. The disaggregate database containing the representative observations are placed in an input file associated with the model. The model is set up to use the appropriate parameters for the run and readied for the analysis. Then, two runs are made. The first is a Base Run or Base Case in which the parameters are set to reflect transportation levels of service and prices that will exist in the BEFORE or current conditions. (This run is also used to validate and calibrate the model's parameters in those cases where the results do not reflect the true mode by which the goods are currently moving as established by the data.) The results are saved for comparison with the policy run in a subsequent analysis. Next, the parameters are set to reflect conditions that will exist after the new policies are placed into effect and the model is rerun (The Policy Run or Policy Case) to develop the AFTER conditions. The difference between the BEFORE and AFTER conditions is the IMPACT of the change in policy, and a Policy Impact Report can be prepared by the user to summarize the findings. Setting up the data for these runs will be presented in a subsequent chapter.

Project or policy to be tested

Population potentially impacted by the project or policy change

Representative sample of decision-makers drawn from the population

Disaggregate choice model used on each observation in the sample to deterrminne choices made by individual decision maker
Logistics choices are:
  Where to acquire
  When to reorder
  What size shipment
  What mode to use

Alterrnative service offerings described in terms of their level of servce attributes:
  Waiting time
  Transit time
  Reliability
  Transport charges

Use aggregation scheme to factor up results to scale of total population

BEFORE = $\sum$ [Individual choices] x Expansion factor **= Base Case Result**

For each project or policy to be tested:

1) Modify the transport level of service attributes to reflect the policy being tested
2) Repeat the use of the disaggregate model on all of the observations in the representative sample

AFTER = $\sum$ [New individual choices] x Expansion factor **= Policy Response**

Use same aggregation scheme to factor up results

3) Compare **Base Case to Policy Response** :
BEFORE - AFTER = IMPACT

The primary difference between the inputs in the BEFORE (Base Case) and AFTER (Policy Case) run is the manner in which the policy is represented. In most cases, the policy changes that are under study can be represented by changes in the level of service models or by changes in transportation rates/prices. Since most of the levels of service are incorporated into the ITIC model parameters, this is not a difficult task. In some cases, the policy change will require a change in the input data used by the observed mode. Where the impact of a new intermodal terminal is being studied, for example, it may be necessary to make changes to the intermodal terminal table used to set up the data for the run.

Data Overview

Preparing the disaggregate observations for input into the model is clearly one of the most important aspects of its use. While the model itself is highly flexible in that many of the parameters can be adjusted to suit the user's specific needs, the development of the input line to the model is the most structured component to model operation. Model inputs include by order for the input line of the model:

1. Serial Number
2. Commodity Description
3. Commodity Code—Standard Transportation Commodity Code*
4. Pounds per Year*
5. Pounds per Shipment*
6. Value of Commodity—Dollars per pound*
7. Origination State

8.   Destination State
9.   Origin FIPS
10. Destination FIPS
11. Observed Mode (*Truck*)*
12. Truck rate per mile for 3S2*
13. Truck highway miles*
14. Truckload per shipment*
15. Number of Trailer on Flat Car (TOFC)/Number of Container on Flat Car (COFC) (*0*)*
16. Rail Junction Frequency (*0*)*
17. Observed Rail revenue per hundred weight (cwt) (*1*)*
18. Rail variable cost per cwt*
19. Rail miles*
20. TOFC pickup miles*
21. TOFC delivery miles*

Note: Items denoted with an asterisk are required fields for performing logistics cost calculations and comparisons. Default values for performing truck to rail intermodal diversions are noted in parenthesis in italics following the item. Each of these items will be explained in more detail later in this document.

For rail revenue, even though the model calculates the value, "1" must be the default value in the field for the model to perform.

For the current version of the model to handle truck-to-rail intermodal diversions, each item by order noted here must be placed in a cell in the input line of the model.

While these are the data needs of the model, the problem is that publicly available sources of disaggregate data are difficult to find. This is true in spite of the fact that hundreds of thousands of shipments are made every day by manufacturing companies and product distributors throughout this country as well as overseas. Each of these shipments is fully documented, the movement is billed for, and the transportation charges paid to trucking companies, railroads, airlines, barge lines, pipeline companies, and other freight carriers. The data collection problem is caused by the fact that it is against the law for carriers to reveal the names of shippers and receivers, the product amounts that are shipped and the origins and destinations of individual movements without that shipper's individual approval. The Bureau of the Census has collected these data in 1993, 1997, and the most recent 2002, and publishes the Census of Transportation.[37] By law, Census must aggregate the results so that the identity of a particular shipper cannot be determined. This aggregation destroys the disaggregate nature of the movement records and renders the information useless for the purposes here.

In spite of these problems, there are ways that a user can proceed. A few disaggregate data bases do exist and there are ways that certain of the aggregate data can be manipulated to serve as the input data needed to run this model. These will be described in the section below.

The Original Mode and the Alternative Mode

In this disaggregate methodology, the "proof" that a shipment of a given size went by a certain mode is typically documented by either a paper, or electronic, record of the movement. A waybill, or freight bill, shows the date of the shipment, the name of the shipper, the name of the receiver, the origin and destination, the size of shipment, the mode, the freight changes, and any special handling requirements. The name of the carrier performing the service is available on some freight bills, but this is typically not needed for the analysis. What is not typically available is the level of service variables that prevailed on the observed mode at the time of the shipment.

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[37] See for example: *The Commodity Flow Study*, Bureau of the Census, U.S. Department of Commerce, Washington, DC, 2000.

These must be inferred from the mileage, the conditions of transit, any terminal operations that were known to occur, etc. Also missing on the freight bills are the total tons of the product used annually by this receiver. The disaggregate input data file must contain all of this data with estimates of those data elements that are missing from the paper record.

Selecting a Source of Disaggregate Data

To perform an analysis using the ITIC model, one begins by identifying potential freight movements that will be affected by the policy change under study. If the question that is being addressed is the ability of a new intermodal service to be able to attract existing truck moves, the disaggregate data base that should be used is a representative sample of individual truck moves. If, on the other hand, the policy question under study is how much diversion of rail traffic is likely to occur if new, larger trucks are allowed on the roadway, the disaggregate data base should be a representative sample of rail movements (both intermodal and carload). The data to be used, therefore, depends on the policy question that is being addressed. The source of potential diversions to another mode or shipment size should be used as the disaggregate sample. The question before us is "where can we get disaggregate data of the type needed for the study?" One can design and execute a sampling program. Origin/destination interviews could be used to develop detailed data on individual freight movements at truck weigh stations, for example. Or, a questionnaire of shippers could develop the required movement data. Obviously, this is expensive and time consuming, and would be difficult to do for many policy studies. The following sections will identify some existing disaggregate databases that can be used with the ITIC model to undertake the type of policy questions we are discussing here and to develop the model's input line.[38]

Rail Carload and Intermodal Data

One of the best examples of an existing disaggregate database is probably the annual Rail Carload Waybill Sample[39] controlled by the Surface Transportation Board (STB), formerly the Interstate Commerce Commission (ICC). These data are a stratified random sample of rail movements collected from railroads in the United States under guidelines specified by STB regulations. The data is used by the Board in rate cases and other legal proceedings before the STB. The confidential file typically contains half a million or so records, each with an expansion factor so that the sample can be expanded to the sample universe—all of the rail movements meeting the STB guidelines in the U.S. for a particular year. Although the records do not contain the name of either the shipper or the receiver, it does contain most of the other information required, including the specific rail station of origin and destination, the name of the rail carriers and the route traveled, along with the mileages and the interchange points. The car type used, the size of the shipment, the rail charges and the variable costs are also presented on each record. It is possible to distinguish a carload movement from a unit train, a multi-car movement or an intermodal movement. The ownership of the equipment can also be distinguished. For rail intermodal movements, it is possible to determine whether the movement is for a trailer on a flatcar (TOFC), a container on a flatcar (COFC), a RoadRailer, or some other special type of rail movement.

Although the Rail Carload Waybill Sample data are not available to the general public, a public use tape is available at a cost, but aggregates some of the commodity and geography data needed by the model. However, portions of it are available to State governments. A State can

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[38] While the version of the model available at this time is for performing analysis of truck-to-rail intermodal diversion, a later version will be made available for rail-to-truck diversion using rail movements as the observed mode in the input line. While that option is not available in the current version, a discussion of the data sources for either operation is included here.

[39] The Rail Carload Waybill Sample is compiled annually by the Surface Transportation Board, which is an independent agency in the U.S. Department of Transportation.

generally obtain copies of those records from the database for any rail movement that originates, terminates, or passes through its state. Permission to use the database is obtained by writing a letter to the STB in Washington, DC, stating the need for the use of the data. If the policy study for which the data is needed is being performed for the Federal Government, or for one of the state or local governments, the data can be obtained by the federal or state DOT. If the study is for a private firm in the transportation, manufacturing, or distribution sector, it is likely that they already have existing freight bills that can be used to accomplish the same purpose as the Carload Waybill Sample. The principle problem will be to determine the transportation level of service that existed at the time the movement occurred for both the observed mode and for each of the alternative modes. This problem will be addressed in a subsequent section.

Truckload Movement Data

Truck movement data is even more difficult to obtain than rail. There is no organized collection of truck movement waybills in the U.S., except that conducted by the Bureau of the Census in the Commodity Flow Survey, and since the Bureau's policy is to release no individual movements to anyone, one must conclude that as a disaggregate data source it is not available. Depending upon the nature of the study and the policy to be addressed, there could be data collected in a traffic origin-destination study by a state or local government that could be useful as the disaggregate database. If so, it might be scaled to equal the total volume of traffic using the aggregate figures from the Commodity Flow Survey, though this is difficult to do. Once again, the level of service of the truck movements for both the observed and the alternative modes must be developed separately.

The Freight Analysis Framework

To overcome this lack of disaggregate data concerning truckload movements, the Federal Highway Administration contracted out the development of a special freight movement database, the Freight Analysis Framework (FAF), to Reebie Associates, a freight transportation consulting firm. Reebie has for a number of years maintained a freight flow database named TransSearch.[40] This database is a compilation of information obtained from cooperating freight carriers. Working from the TransSearch data, Reebie prepared a special disaggregate version of the database, which provides a freight flow foundation that can be used in the ITIC model.[41] Although the records are not individual waybills, the movement data are very disaggregate, representing the truckload movements between a given county of origin and a single county of destination at a very detailed commodity STCC level in a particular truck body type and axle configuration. The FAF database contains movements for a 1998 base year, and projections to 2010 and 2020 developed by Global Insight, Inc. These are useful for planning purposes. Since long haul intercity trucks are typically fully loaded except when repositioning, the shipment size can be inferred from the commodity code. The level of service of the observed movement is usually closely related to the mileage traveled. The transportation charges associated with the movement and the levels of service of the alternatives must still be determined. We will address how that can be done in a subsequent section.

Once again, the use of this FAF data by anyone outside of the U.S. Department of Transportation poses a barrier to its widespread use. On the other hand, Reebie Associates can probably be contracted directly to provide the data needed for a particular study should that

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[40] *TransSearch* is a national freight movement database from which excerpts of data can be purchased from Reebie Associates, Inc. in Greenwich, Connecticut. (In February 2005, Global Insight, Inc., acquired the assets of Reebie Associates.)

[41] The FAF provided the basis for the data for this version of the model when FRA performed the PTC analysis.

necessity arise. However, a version of the data aggregated at the state-to-state and two-digit STCC level is publicly available from FHWA.[42]

Developing the Other Inputs

In general, for the **observed** mode, some of the inputs, including the origin and destination, will be available from the disaggregate data; while for the **alternative** mode, the entire set of inputs will need to be developed. (The alternative mode would use the same origin and destination as the observed mode.) However, a number of the inputs to the ITIC model are typically not available from the disaggregate movement records. These include the highway mileage, intermodal pickup and delivery (drayage) distances, the principal commodity attributes (lbs/cu ft, $/lb), the truck payload and rates, and the rail variable cost/cwt. If rail is the observed mode and the Carload Waybill Sample is used as the disaggregate input, rail miles, equipment choice, transportation charges and junction frequency will be available from the Waybill records, but all of the alternative truck mode inputs will have to be developed. If truck is the observed mode and the Freight Analysis Framework is used as the disaggregate input, all of the alternative rail mode input, will need to be developed. It should be noted that the ITIC model (as it is presented here) uses mileages and a set of predefined relationships to develop many of the level of service variables, including the waiting time, the transit time and the reliability of the arrival for each of the modes based upon parameters in the model that can be easily modified for the different scenarios. Some notes on potential data sources and methods for developing some of this missing input follow below.

Trip Miles

A number of sources of mileages between points exist. Any reliable source can be used. One source for truck miles and rail miles between county centroids was prepared by the Oak Ridge National Laboratory (ORNL) for the U.S. Forest Service.[43] This data source uses a detailed replica of the Federal and State highway network. The geography in a lookup table is 5-digit FIPS code,[44] which gives the truck and rail mileages between any county in the U.S. This data is publicly available.[45] The Carload Waybill Sample also includes rail miles and is considered to be an accurate source for miles between origination and destination for rail movements. The user may prefer these rail miles that are included on the Waybill Public Use file, available to all users from the STB at a cost.[46]

Handling Intermodal Terminals and Dray Miles

If rail intermodal is the alternative mode (the application in this version of the model), the origin and destination of the movement is known from the observed mode movement in the disaggregate data or from other information developed by the user. Here the problem is selecting the intermodal terminals that should be used to make the trip. If one knows where the intermodal terminals are located, it is not difficult for the user to select the most convenient. FRA has developed a lookup table for the user to select the rail intermodal terminals nearest to the

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[42] Contact the FHWA website at www.FHWA.DOT.gov.

[43] Oak Ridge National Laboratory, *A Network Model of the Interstate and Federal Highway Systems*, Oak Ridge, Tennessee, 1998.

[44] A 5-digit FIPS code is the U.S. Department of Commerce Federal Information Processing Code designating U.S. counties. A 2-digit code designates a state.

[45] This data is available from FRA on CD.

[46] Rand McNally and ALK Associates produce software to calculate highway miles and rail miles. These products are commercially available from them.

counties of origin and destination of the movement. The drayage miles to and from the terminals are calculated as straight-line distances with an 18 percent circuitry factor.[47]

If rail intermodal is the observed mode, the originating and the terminating terminals are known from the Carload Waybill Survey. Still unknown, however are the actual locations of the shipper and the receiver. These could be in the same city as the intermodal terminal, or they could be located in a nearby city and drayed to the intermodal terminal. If the intermodal terminal is "on the general path" of the movement it could even be quite distant, but likely to be close enough that the drayage operator could both pick up the shipment and return to his home base in one day. One way to treat the drayage distance input to the model is to select an origin or destination city at random from the list of cities nearby the intermodal terminal and to compute the drayage distances and the linehaul distance for the alternative mode from these choices.

Commodity Attributes

The ITIC model uses two commodity attributes in its computations. These are the density, measured in pounds per cubic feet, and commodity value, measured in dollars per pound. These are available in a 2-digit STCC Commodity Attribute File.[48] Because the same commodity is likely to be packaged differently and be of higher value if it travels by truck than it is if it goes by rail there are two files, one for products observed moving by rail, the other for those being transported by truck. This distinction is made because the value of the commodity is an important aspect of the inventory carrying costs entering the shipper/receiver calculus for choosing a mode. An example—if flour is observed traveling by rail, it is likely bulk flour moving in a covered hopper car. If salt is observed traveling by truck it is more likely to be a truckload of higher valued, small, one-pound packages in a cardboard carton. The value and density will be affected by the refined nature and consumer packaging of the product.

Annual Use of the Product

Developing the annual use of a product by the receiver is one of the most problematical things to be done in running the ITIC model. Yet, we know that annual use is clearly the most important determinant of shipment size. For observed rail movements one can use the Rail Carload Waybill Sample to develop this information. By sorting the waybill data to group all of the movements of a particular commodity destined to a single point and summing the tons carried,

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[47] To calculate the drayage distances to the nearest rail intermodal facility, FRA started with an area database (layer) of the counties of the U.S. produced by the Bureau of the Census. FRA then extracted the location of the centroid along with FIPS identifier for each county. A database of intermodal facilities was searched to identify the nearest to each centroid. "Nearest" was defined by the minimum "separation" between the longitude/latitude coordinates of each centroid and the longitude/attitude of intermodal facility points in the intermodal database. "Separation" was defined by taking the square root of the sum of the squares of the differences in both longitude and latitude.

Next a table was created of the coordinate pairs—longitude/latitude of the centroid, longitude/latitude of the nearest intermodal point. A geographic information software package was then used to determine the distance in straight-line-miles between each pair of coordinates.

The output was turned into a table consisting of the original county identified by its FIPS and a distance to its nearest intermodal point. An 18 percent, circuitry factor was added to account for the fact that no transportation system travels in a perfectly straight line. This increased value then became the drayage distance.

In determining the total distance for an intermodal move three pieces were combined: the drayage from the originating county, the drayage to the termination county, and the rail distance between the counties of the intermodal points as determined by the ORNL county-to-county lookup table.

The lookup table is available on CD from FRA.

[48] An aggregated *Commodity Attribute File* at the 2-digit STCC level is included on the CD ROM with the model.

you have a proxy for the amount of that good used by a single receiver at that point—the annual use. Obviously, the more exclusive the definition of the origin and destination (FSAC) [49] and the more defined the product (7-digit STCC), the better the result. A FSAC is the Freight Station Accounting Code used by an individual railroad. A FSAC is typically the loading or unloading point of a single receiver.

For truck movements or intermodal movements the annual use is typically much smaller than for shipments by rail carload. Annual uses of less than about 250,000 pounds per year (about five truckloads) will almost certainly go by truck, especially if the product is expensive, or the product has a short shelf life. Above a million pounds per year, the low cost of transporting a 200,000-pound carload shipment by rail begins to become more and more attractive. If the development of annual use rates for observed truck shipments is impossible, one could use a Monte Carlo simulation to draw representative use rates from a distribution. County Business Patterns[50] reports by 4-digit Standard Industrial Classification (SIC) code the number of firms by size that exists in each county in the U.S. This can be used to help develop a typical use rate distribution for use in the process.[51] **However, implicit in the FAF, the annual use is considered to be the volume on each record.**

There is typically no fundamental difference between the use rates of a product traveling by TOFC rail and one moving by truckload truck. Consequently, if the policy question is concerned with diversion from TOFC-to-truck, or from truck-to-TOFC it doesn't particularly matter what the annual use rate is, because the shipment sizes that can be used by the two modes are essentially the same. The tradeoffs that matter in choosing the mode are difference in rates and service quality. At the same annual use, low value and high density would appear to favor TOFC, while high value and high cube would tend to favor truck. COFC movements are typically international shipments, so these same conclusions don't necessarily hold.

Truck Payloads

The amount of product that can be carried in a truck is a consequence of the truck size and weight laws that exist at a given point in time. These laws are quite complex, involving axle loadings and their spacing as dictated by the Bridge Formula.[52] They are also different in some of the western states and in Canada, in part because at the time the upper limit on weight was set at 80,000 pounds, these states already allowed higher weight limits. Consequently, they were grandfathered in at the higher weights. Travel on the Interstate Highway System beyond the state borders, however, is currently limited to a total weight of 80,000 pounds. Consequently, the amount of product that can be loaded into a truck is 80,000 pounds less the tare weight of the empty truck. For a heavy-loading commodity, like bricks for example, the payload is around 50,000 to 55,000 pounds. For a light-loading commodity like Styrofoam balls, the payload may be only 20,000 pounds because the trailer cubes out before the weight limit is reached. It should be noted that the weigh out vs. cube out aspect is a function of preprocessing based upon the commodity weight per cubic foot and the available cubic feet for loading. Understanding the applicable truck payload weight is, of course, key to the number of truck trips associated with the annual use rate.

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[49] *Freight Station Accounting Code Directory*, Association of American Railroads, Accounting Division, American Railroads Building, Washington, DC, 20036.

[50] *County Business Patterns* is issued annually by the Department of Commerce, Bureau of the Census, Washington, DC.

[51] Chiang, Y.S. and P.O. Roberts, *Representing Industry and Population Structure for Estimating Freight Flows*, MIT Center for Transportation Studies CTS Report 76-8, Cambridge, Massachusetts, August 1976.

[52] The Bridge Formula is a formula used by highway engineers to define limits on the weight and spacing of roadway wheel loadings of highway vehicles for use in bridge design.

Freight Rates

Developing the freight rates to use as input for those observations in the disaggregate database that do not have them, or for the alternative modes, is one of the most difficult tasks to be undertaken in the data preparation phase. Freight rates are important competitive tools and companies guard them closely. In the largely deregulated freight market that currently exists, tariff rates, where they do exist, are largely unused. Most rates, both truck and rail, are individually quoted for that customer only, and apply exclusively for that traffic lane. Consequently, a range of rates exists in any given market. Our challenge is to find a rate for each of the modes that are representative of the market as a whole. One thing is abundantly clear—the rates are not strictly the cost of offering the transportation service. In trucking, for example, there is a cost of getting an empty vehicle back home. Rather than return empty it is better to offer transportation service at below the average cost per mile of travel. Anything is better than nothing. In fact, the truckload industry has developed a method of operating that allows a vehicle to move from place to place, as loads are available. The driver leaves home for a tour of duty that may last several weeks. As he delivers one load, the dispatcher for the company finds another load for him going to a different city. The driver rests in the truck sleeper after driving the maximum allowed hours of service, and also between loads. In due course, the dispatcher finds a load originating near where the driver delivered the last load that will terminate near his home base. He may spend several days at home before going back on the road.

Truckload Trucking Rates

Truckload rates for dry van movements are extremely competitive throughout North America. Although there is a great deal of spread in observed rates, even on the same traffic lane, overall rates appear to reflect the repositioning costs needed to correct the equipment imbalances described above. In the real world, competition drives the rates to adjust for these load imbalances. The rates observed for truckload movement in each city-pair market tend to reflect this phenomenon. As indicated earlier, this occurs because the number of loaded trucks moving into some regions is larger than the number of loads desiring to move out. Trucks carrying goods out of an equipment surplus region typically charge a lower rate because they know they will have a difficult time securing outbound loads and must either lower their outbound prices or wait longer to get a load. When more loads move out of a region than move in, there is typically a shortage of equipment. Shippers are willing to pay more to attract a carrier. Consequently, outbound rates from an equipment deficit region are typically higher.

A company named Class 8 Solutions has developed one source of current truckload dry van rates from information gathered from individual trucking companies .[53] These rates consist of a 120 by 120 matrix of major market pair cities located throughout the United States. The figure in each cell of the matrix is a representative of the dollar-per-mile rates that currently exist for transporting a full truckload of product between the two markets. The matrix is located in an Excel workbook. A separate spreadsheet assists the user by performing a lookup of the rates for a market pair in the table of individual origin to destination rates using zip codes. One enters the zip code of the origin and the zip code of the destination and the routine locates the proper cell for that market pair in the 120 x 120 matrix. The final freight charges then are the $/mile truckload rate figure in the matrix, times the actual miles between the markets. Even though the specific zip codes for origination/destination may not match those identified by the matrix, the routine locates the closest city in the matrix based upon the zip code entry associated with the FIPS code of counties of origin/destination. While freight flow data sets, such as the FAF, may not contain origins and destinations based upon zip codes, the user will find it necessary to bridge the gap between the origination/destination format available on the data set with the zip code format used by Class 8 Solutions. For example, it the freight flow data set contains originations/destinations

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[53] While the Department has used Class Eight Solutions rate matrix in previous studies, our use of it here does not mean that this is sole product of its type. The presentation here should serve as a guide to the user when considerations are given to obtaining truck rates.

based upon 5-digit FIPS, then a corresponding zip code will need to be identified. The U.S. Census provides a table of zip codes with corresponding FIPS codes, including state and county names.[54] By using this table the user should be able to identify the zip code from the given FIPS. Consequently, the appropriate rate for the any city pair in the 120 x 120 matrix can be determined by using the FIPS to zip lookup table.

Rail Carload Rates

As indicated earlier, rail carload rates are typically shown in the Carload Waybill Sample. Consequently, for rail carload as the observed mode in the disaggregate data no additional effort is required. Where rail carload is a legitimate alternative that should be considered by the shipper, it is necessary to develop carload rates for use in the model. Such a model was estimated from observations drawn from the Waybill Sample for use in the SAIC version of the model.[55] This model turned out to be too variable for most uses. However, this is not a problem when highway is the observed mode and rail intermodal the alternative. Discussions with rail management have indicated that the intermodal rate is actually a discount from truck door-to-door rates.

Rail Intermodal Rates

The rail intermodal price consists of two parts, the line haul portion and the drayage. In this version of the model, the rail intermodal door-to-door rate is derived from the truck rate, by setting the intermodal rate at a discount to the truckload door-to-door rate. (The default rail intermodal door-to-door rate in the model is set at 95 percent of the truck door-to-door rate or, in other words, a 5 percent discount off of the truck door-to-door rate.) This figure was arrived at from interviews with railroad intermodal marketing departments. The discussions centered on how rail would competitively price a truck market in an attempt to capture business.

The drayage portion of the rail intermodal freight charges are set at $125 for the first 30 miles plus $1.38 per mile for each mile beyond 30. For example, if the dray on the pickup portion is 5 miles then the charges are $125. If the dray in this case is 31 miles, the total dray for pickup is $126.38 ($125+$1.38). A similar calculation would be done for dray on the delivery end.

Rail Variable Cost

Rail variable costs play a role in deciding what traffic to accept and what to reject. When intermodal rates calculated by the model from the procedure described above fall below 110% of rail variable costs, plus drayage costs for the move, the load is refused by rail and allowed to select truck at its original truck rate. Variable cost is increased to assure a minimum contribution to the railroad's overhead. As other assumptions in the model, it is flexible and can be changed by the user. These figures are used to limit possible diversion to the rail mode. Clearly, rail management does not want to compete aggressively to attract (or to hold on to) traffic where the revenues are below short-term variable costs.[56] Also, In terms of the model, including drayage costs in the acceptance threshold assures that inordinately distant, and consequently costly, shipment origins/destinations from intermodal terminals will be rejected.

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[54] The table of Zip codes with corresponding FIPS codes including state and county names are available from Census at http://www.census.gov/geo/www/tiger/zip1999.html.

[55] SAIC report, Op. Cit. 1997.

[56] If the user is unable to obtain rail variable cost, the model will calculate that cost wit a simple cost calculator. (To invoke this feature, the user should input "unknown" for rail variable cost per hundredweight in the input line.)

Benefits Analysis

The direct economic benefits of a policy change that impacts the logistics cost of shippers can be developed directly from the model output. This is possible because the model measures the change in the shipper/receiver utility function in dollar terms caused by shifting from using one alternative to using another. The logistics cost savings is the direct dollar saving to the shipper of making the shift.[57] When aggregated over all shippers it is the first round economic impact of the policy change. If, for example, a new TOFC service is able to attract users away from their existing mode of transportation, the change in the total logistics cost of shifting to the new, lower cost mode is fully reflected in the shipper's reduced total logistics costs. By aggregating this savings over all shippers, the entire initial dollar saving of the shipping community is developed. This saving will be reflected in the company's profitability and can be saved as retained earnings, kept by the owners, passed on to customers in the form of lower prices, or poured into hiring new staff and expanding the productive capacity of the firm.

It should be noted that the first round economic impact is just that—a first round. Once the savings has been distributed, it could result in further growth in the economy of the trading regions. The best way to measure these secondary and tertiary economic impacts is to employ one of the macroeconomic models that can use the logistics savings outputs of the ITIC model as an input to the macroeconomic model and trace the flow of economic impacts that emanate from this first set of economic savings.

Components of the ITIC Model

The coding of the ITIC-IM model employs the same logic and format as that used for the DOT's Comprehensive Truck Size Weight (CTS&W) Study, submitted to Congress. One advantage to this version, however, is a substantially enhanced user interface with the addition of a sheet called "Running Macros" within the model that provides the user with an ease of operation by simply clicking buttons to perform base case and policy scenarios. Additionally, the model provides summary statistics, which allow side-by-side comparison of the Base as well as the Policy Case for both truck and rail intermodal. Aside from these features built into the model's macros, the logic embedded in the "TSW" worksheet is fundamentally unchanged, but some modifications have been made in the input/output records to simplify the operation.

Unlike the CTS&W Study, the ITIC-IM model focuses on the issues facing transportation policy makers and planners looking toward the projected doubling of truck freight by the year 2020. These groups are focusing on how to increase rail intermodal's share of freight movements, as well as, other alternatives. Here, the ITIC-IM model provides a tool to measure potential changes to shipper's mode choice following a given change, for example, in the relative price and reliability of rail intermodal service offering. In the future, additional features incorporated into subsequent versions will increase ITIC's usefulness as a series of flexible transportation tools. Results from the model can provide input to examine other important mode choice impacts including: infrastructure investment, safety, energy, environment, and traffic operations.

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[57] The model is an all or nothing choice based on a comparison of total logistics costs. There is a threshold saving the shipper can be expected to apply before it becomes worthwhile to make the mode shift. In the model that threshold has been set at 3% of the annual freight cost or $20,000, whichever is less. The user of course can change these parameters.

Overview of The Model Structure

The ITIC-IM model consists of a series of Excel[58] spreadsheets in an Excel Workbook, which are set up to run on a personal computer. The spreadsheets contain: 1) the basic model (sheet "TSW"); 2) sub-components of the model that perform special computations (sheets "Rail" and "Truck"); 3) supporting lookup tables or locations where the user can define or store model parameters in support of a particular scenario (sheets "Assumptions" and "Assumptions Default"); and 4) documentation that explains the components of the model and a place for user notes (sheets "Doc" and "User Notes"). Finally, the sheet "Running Macros" allows the user to operate the model quite easily by clicking on the appropriate box for the desired operation.

First, this manual will briefly describe what is in each of these sheets.

Running Macros Sheet

As noted above, this sheet provides the user with a seamless method of operation to perform policy analysis. The macros underlying each of the buttons automate several of the processes associated with using the model. The two colored boxes are for using truck freight flow data stored in an Excel worksheet (preferably located in the same computer folder as the model but not a requirement) to run the base case or a scenario run testing truck-to-rail intermodal. There is also a button provided for resetting the assumptions sheet to the defaults provided by DOT. The function of the boxes and buttons will be demonstrated in a following section called "Running the Model." But first, an overview and brief discussion of the colored boxes on this sheet are necessary.
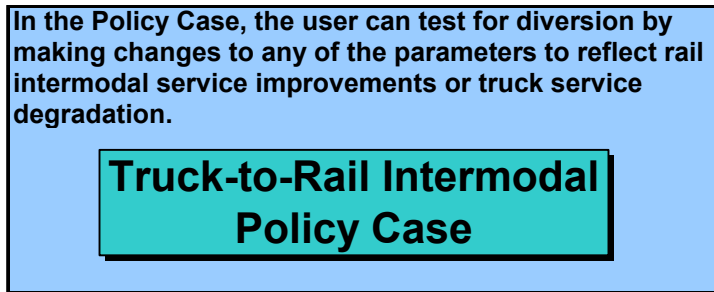
Macros for Truck-to-Rail Intermodal Base Case and Policy Case (Blue box)

> **The user must run the base case first. If a truck record choses rail in the base case, it is considered to be "mis-assigned" and is not included in the policy run of the scenario**
>
> ## Truck-to-Rail Intermodal Base Case

Base Case – THE USER MUST RUN A BASE CASE BEFORE A POLICY CASE WILL RUN. In the "Base Case" this macro processes each truck record through the model from the external Excel workbook, named *truck itic input.xls*. The design of the macros requires that the base data input sheet be called "Sheet1" (which is the default name provided by Excel). Any record that is observed diverting to rail intermodal in the base case is considered a "mis-assigned" record and is not considered for the Policy Case. A clean data set for policy analysis is written to "Sheet2." A user is strongly urged to review the records that have been "mis-assigned" on "Sheet3" of the *truck itic input.xls*. This can provide a user with useful information to correctly calibrate the model variables.

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[58] The CD-Rom also includes a copy of Excel Viewer. This will allow a person who does not own Excel to view (not edit or run) the ITIC-IM model. The Excel Viewer is also available online at http://office.microsoft.com/en-us/assistance/HA010449811033.aspx?Query=viewers&Scope=TC,HP,HA,RC,FX,ES,EP,DC,XT

Policy Case - After making the desired changes in rail intermodal service parameters, click the button "Policy Case." This operation processes each record from *truck itic input.xls* "Sheet2" through the model to check for diversion potential. It then writes the results to "Sheet4." Here the records processed through the model are recorded with complete model results. It includes those highway moves that diverted to rail intermodal and those that chose to remain on the highway.

Macro to Reset Defaults (Green Box)
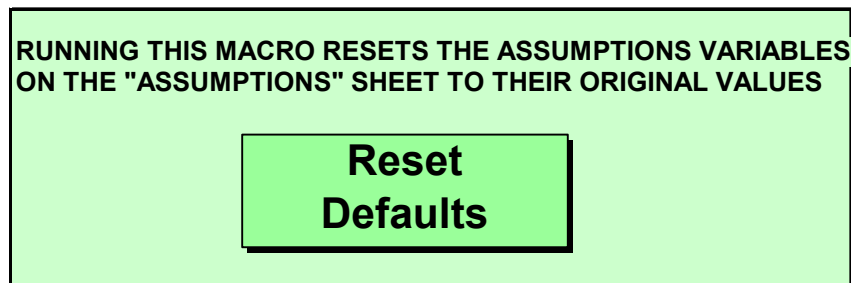
Reset Defaults – By selecting this tab the user can copy the "Assumptions Default" worksheet over the "Assumptions" worksheet. This will reset the assumptions back to those contained in the original model. The flexibility of the model, however, allows the user to determine the value of those parameters that are appropriate for the analysis at hand. These default parameters are offered as a starting point for the user.

Output Summary Statistics – Following each run of the model the summary statistics will appear to the right of the scenario choice on the "Running Macros" worksheet. This section of the worksheet provides the user with a compilation of statistics from the Base and Policy Case runs. It is intended to offer a quick capsule of statistics for comparison so the user will not have to work through the vast amount of data contained in the output spreadsheet. Users are cautioned that the results will be deleted when a new base case or new policy scenario is run. Users should copy results that they wish to save to an outside worksheet with a brief description about what made that run unique.

TSW Sheet

This spreadsheet is the heart of the model. Variables from the disaggregate data file and the input parameters are used to compute the level of service components of the shipper's logistics cost function for the observed mode and for each of the alternatives. These, in turn, are used to determine the selected mode.

The input for each record—a single observation in the disaggregate database—is presented to the model in a single row at the very top of the spreadsheet. Information from this top row is distributed to those points in the computation where it is needed (the audit function in Excel is extremely useful for tracking that distribution). The logistics cost computations are performed in the spreadsheet. For each of the modes, including the observed mode, logistics cost are developed and presented in the appropriate column of the spreadsheet. Generally, the mode with the lowest total logistics costs is selected to be the winning mode. The exception is that for rail intermodal to divert traffic from truck, its logistics cost must be lower than truck by a threshold limit supplied in the input data. On the other hand, as noted above, when rail is the observed mode it is allowed to lower its price to keep a load that was originally observed to move by rail, but only to the short-term variable cost level. This lowers rail yield, but avoids losing money by carrying traffic below cost. This applies only when testing from rail-to-truck, i.e., when rail is the observed mode. In the truck-to-rail intermodal version of the model, where truck is the observed mode, truck rates are not lowered when faced with improved more competitive intermodal price/logistics costs. Because the truck industry is low fixed cost and highly competitive, there is no room to cut truck prices. At least that is the assumption in the truck to intermodal version of the model.

Once the low cost mode is selected, the results are placed immediately in the output row—row 5. When running the macro, this row (row 5) is copied to the *truck itixc input.xls* workbook.

Assumptions Sheet

This spreadsheet contains not only many of the assumptions affecting level of service variables for the base and policy runs, but two important tables—the Service Level Parameter Table (Table 1) and the table of Mode-Equipment Options and User Supplied Input Parameters (Table 13). The Service Level Parameter table (cells F5 – I46) shows the probability of no stock out during the replenishment cycle, for each 2-digit STCC product. It also shows assumptions concerning carrying cost in percentage terms for each 2-digit STCC product. Carrying cost in this instance includes interest on the capital cost of product tied up in inventory, insurance, taxes, obsolescence, pilferage, transfer, handling, and storage used for cycle stock and safety stock. These figures represent default values, but can be changed by the user if the policy under study demands it or more up to date data are available.

Table 13, the Equipment Options and User Supplied Input Parameters (cells K5 – N11), lays out the equipment options that are to be made available in the model. For each, the wait-time in days, the relative transit time reliability, the loss and damage experience of the mode as a percent of gross freight revenue, the claim payment days and a row to indicate whether the mode is to be included in the analysis are presented. Included in this table are default settings for wait time, reliability, loss and damage and claims payments for each respective mode. Again the user is strongly encouraged to seek more complete and relevant information for their particular application.

The table entitled TSW Model Parameters (cells B5 – D25) contains parameters used in the computations, including: a cost figure for ordering cost, interest rates for use with the cost of capital involved in damage claims and in-transit movement, and TOFC and COFC average line haul mph. The next portion of the table shows the average miles-per-hour (mph) for the base truck. Other variables in the table include:

- load/unload hours – time necessary for the driver to empty the trailer;
- wage rate/hr w/fringe –wage to the driver during the loading and unloading;
- pickup $/ship - cost from the drayage operator to pick-up an intermodal trailer/container, currently set at a flat rate of $125 if under 30 miles;
- pickup $/mile – cost per mile for bringing the trailer/container from the shipper to the intermodal yard for loading, currently set at $125 plus $1.38 for every mile above 30 miles;

- delivery $/ship – cost from the drayage operator to load the trailer/container at the intermodal yard, currently set at a flat rate of $125 if under 30 miles;
- delivery $/mile – cost per mile for bringing the trailer/container from the intermodal yard to the final destination, currently set at $125 plus $1.38 for every mile above 30 miles;;
- dwell time at origin and destination terminals – dwell time accounts for the unit at the intermodal terminal, currently set at 0.5 days at origin and 0.5 days at the destination
- proxy for rail junction/interchange delays – when analyzing a truck shipment, replacement with rail service may require a junction or interchange between railroads. The default is set for 1.5 days but can be adjusted;
- Additional fee per mile – this adds an additional cost to the standard base truck cost per mile
- One time additional fee – an example is a special license or single use fee that may be charged the alternative truck;
- Pickup $/ship – per-trip cost of moving the trailer to the permitted road system;
- Pickup $/mile – per-mile cost of moving the trailer from the shipper to the permitted road system;
- Delivery $/ship – per-trip cost of moving the trailer from the permitted road system;
- Delivery $/mile – per-mile cost of moving the trailer from the permitted road system to its final destination.

Rail Sheet

This spreadsheet contains two important tables used in the model computations. The first, entitled "Summary of Rail Transportation Cost Elements" computes the rail transportation charges. Here, the various elements involved in determining the freight charges for rail are assembled to determine the observed charge per shipment. Remember that the rail intermodal rate is computed as 0.95 times the competing truck door-to-door charges, as previously noted. Again, the user is encouraged to change this value if more up to date or information is obtained for the analysis at hand.) A side calculation of the total variable cost including dray charges and contribution is performed in the blue box in cells H9:J14 on the "Rail" spreadsheet. Additionally, this sheet contains a simple rail variable cost calculator, if the user is unable to obtain reliable rail line haul variable cost. (See Note 56 for invoking this feature.)

Truck Sheet

Truck freight charges are computed in a table on this spreadsheet. Included in the computation is the cost to load and unload the vehicle, the linehaul rate of the move, and a cell for additional fees that the user can test the effects of tolls on highway segments. The model is currently set up to use only one truck type (a 3-S2).

Doc Sheet

This spreadsheet contains notes on the spreadsheets involved in the model, the macros used, dates of revisions, and other notes.

User Notes Sheet

This is a blank worksheet provided to the user for comments and notes on runs. This makes an excellent location for comments back to the model development team.

Assumptions Default

This worksheet contains all the default values that were provided for in the original ITIC-IM model. FRA and FHWA provide default values as guidelines; users are strongly urged to obtain data relevant to their analysis issue. This sheet, provided as an additional tool in conjunction with the Reset Defaults macro, also enables the user to revert back to the base case parameters quickly rather than locating and changing those cells back to their original values.

Assembling the Input Variables in the Disaggregate Data File

The format of the input for each line of the input data in the input file is shown below, along with an explanation of the variable and units involved. Note that the data for each individual observation is entered in a single row of the input data file. The data input is organized into the following categories: commodity; location; observed mode; and rail alternative information. The following is a listing of those variables and the order that they must appear for input into the model. Note that all dollar values in the sample input file and the model are year 2000.

Serial number – It is useful to have a unique number associated with each record in the input file. This way if anything is wrong with the output the input can be identified, recovered and analyzed.

Description – This is the description of the commodity associated with the Standard Transportation Commodity Code.

STCC – the Standard Transportation Commodity Code developed and administered by the Association of American Railroads.

Lbs/yr – Annual use of the product being shipped by the receiver in pounds per year.

Lbs/shpmt – Shipment size in pounds (normally the maximum product that can be placed in the vehicle).

$/lb – Value of the product in dollars per pound as packed and shipped on the observed mode.

Ostate – The 2-digit abbreviation of the U.S. state, or Canadian province, or Mexican department in which the move originates.

Dstate – The 2-digit abbreviation of the U.S. state, or Canadian province, or Mexican department in which the move terminates.

Ofips – The 5-digit FIPS number of the county of origin as designated by the Bureau of the Census. (In the sample data, only 2-digits FIPS is provided.)

Dfips – The 5-digit FIPS number of the county of termination as designated by the Bureau of the Census. (In the sample data, only 2-digits FIPS is provided.)

Obs mode – The mode on which the shipment was observed to be traveling. For the ITIC IM model this is always "truck."

Cost/mile 3S2 – Price charged by trucking company for utilization of a standard tractor semitrailer divided by miles, $/mile. The abbreviation 3S2 stands for "three axle tractor with a two axle semitrailer."

3S2 Miles – Truck miles from shipper's loading dock to receiver's loading dock in miles.

3S2 Load – maximum payload weight allowed on the truck subject to the legal restrictions, cubic capacity of the truck and the pounds/cubic foot of the product. For example a 3S2 van with a tare weight of 30,000 pounds could potentially load 50,000 commodity pounds or if the commodity is "high cube" then the 3S2 load could be lower. The cubic capacity is derived by multiplying the length of the trailer less 6 inches by the width of the trailer less 4 inches times the height of the trailer. For a 53-foot trailer the cubic capacity is approximately 3,930 assuming a 102-inch width and 9.16 foot height.

num TOFC/COFC – If the observed mode is rail, num TOFC/COFC is "1" for rail carload, "2" for TOFC or "3" for COFC.

Junction Frequency – This field is used to accommodate a railroad junction when analyzing truck moves. It contains either a 0 for no junction or a 1 for a junction. It is assigned by the user to handle rail junctions and interchanges if an interchange between carriers is required.[59] It is used in computing rail transit time and is currently set at 1.5 days.

obs rail rev per cwt – Rail revenue per car divided by shipment size in hundredweights, $/cwt, (cwt =100 lbs).

rail VC per cwt – Rail variable cost per hundredweight.

rail miles – Rail line haul distance in miles.

tofc pu (tofc pick-up) – Distance from shipper's loading dock to origin intermodal terminal in miles.

tofc dlvr (tofc delivery) – Distance from destination intermodal terminal to receiver's loading dock in miles.

Steps Involved in Making an ITIC Run

Once the disaggregate data file is available and the data has been placed into the format described in the previous section, the steps required to make a run of the model are relatively few.

The user should place the data in a separate Excel workbook preferably located in the same computer folder as the ITIC model but not an absolute requirement. **The spreadsheet must be named *truck itic input.xls* and must be open before the model can process the records.**   This workbook contains four spreadsheets. The first is titled simply "Sheet1" and contains truck flow data for input. "Sheet2" will contain clean data void of mis-assignments following the "Base Case" run. "Sheet3" contains the logistics cost and other statistics generated by the model for the records in the base case. To operate the model in this type of file, the user simply clicks the "Base Case" button in the box titled Macro for processing truck flow data in another Excel Workbook" (Blue box). Following service parameter changes, the user can test for the potential diversion by clicking on the button "Policy Case" located in the same box. A message will instruct the user following this operation so that the diversion results for review are located in "Sheet4" of the same file.

The current version of the model already has a sample data set in this spreadsheet, which can be used as a template. If the user has prepared truck flow data then those records can simply be placed in this spreadsheet for operation. As noted above, the user simply clicks the "Base Case" button in the box titled "Macro for processing truck flow data in this workbook" (Blue box) on the sheet "Running Macros."   Following the models review of the data for mis-assignments in the base case, the user is ready to test the potential for diversion with changes in service parameters. The user then clicks the appropriate "Policy Case" button.

The Base Case button in this box and in each of the boxes for operation described below also performs a useful function. The operation serves as a check on the calibration of the model parameters and incoming data. This can be explained in the following way. The original data set will come from a source that indicates that the original observed movement came from a particular mode—here truckload shipments.   The user has prepared the input data using estimates of the level of service of both rail and truck that were assumed to be valid at the time the original observation was made.   When the data is run through the model, some of the observations, however, may choose to go by rail intermodal. We refer to these observations as "mis-assigned"—because they chose rail intermodal when they have been observed as moving by truck. If there are a large number of these mis-assignments, it indicates that the assumptions concerning the level of service of one or the other of the modes needs to be revisited. If there are

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[59]   For example, in FRA's PTC analysis, certain truck moves traversed the country.   To consider a comparable rail move, FRA inserted a rail junction since an interchange must occur between east and west carriers.

only a small number of mis-assigned observations, then the easiest way to handle them is to drop them out of the data set, unless other questions persists. In the examples that will be reviewed later, these records will be removed from the data set. The Base Case performs this check. It reports the records available for review from the total record set.

The Base Case also checks to see if the calculated rail rate is less than 110 percent of rail variable cost plus dray. If such moves are detected then they are not included in the data set for policy analysis. Further explanation and examples are provided below in Example 2.

Quick Start: Examples for Running the Model

The following section contains two examples and explanations on how to run this version of the ITIC model. Immediately below is: "Example 1: Running the Model on a Single Test Record," followed by "Example 2: Testing truck shipments for potential diversion to rail intermodal" where the truck flow data is in the sample set "*truck itic input.xls*."

Example 1: Running the Model on a Single Test Record

As noted above, the model can be run in a number of different ways. Using the buttons incorporated in the spreadsheet, "Running Macros" the chosen macro reads a record from "Sheet1" of data file and writes it into the "TSW" worksheet of the ITIC model. It then writes the results to another spreadsheet in the data file for further analysis. The model can also handle one single record at a time from inputs entered by the user to the proper cells on the spreadsheet. (Users can also copy and paste a record into the input line if it is in the correct data order.) The following will show how the model can be operated in this form, one record at a time, with test data. It is recommended that a first time user employ this one-record-at-a-time method to acclimate themselves to the model and its logic. By entering the data into the cells noted below, the calculations will flow through the spreadsheets to give the results.

Base Case:

Step 1. The first step is to open the model in Microsoft Excel and enable the macros. If you are unable to allow the macros to operate, you may have the security setting too high within Excel. To remedy this problem click on Tools, look for Macro, and then click on Security under Macro. Choose the Medium setting.   You must close the ITIC file, and then open it again. Once open it should appear with a box to enable macros. Click "Enable Macros."

Step 2. After opening the model, if the TSW sheet is not displayed on the screen, click on that sheet from the bottom of the page to make it active.

Step 3. You will note that the input line for data inputs is at the top of the TSW sheet, beginning in Cell A2 and running through Cell U2. As noted earlier, the order of the input line is very specific to operating the model.

Step 4. Here a test record from below will be entered into the model's input line. Some inputs are descriptive and are not essential for determining logistics costs. Such inputs can be left out or some value or text can be used to occupy the cell. However, to maintain the detail of a move, no data should be excluded. Other inputs essential for determining logistics cost will also be explained. The record to begin with is as follows:

TSW SHEET

CELL	FIELD NAME	VALUE
A2.	Serial Number	1
B2.	Commodity Description	Soft Drinks
C2.	Commodity Code—Standard Transportation Commodity Code	20
D2.	Pounds per Year*	984,525
E2.	Pounds per Shipment*	35,328
F2.	Value of Commodity—Dollars per pound*	0.25

CELL	FIELD NAME	VALUE
G2.	Origination State	NJ
H2.	Destination State	WA
I2.	Origin FIPS	34
J2.	Destination FIPS	53
K2.	Observed Mode (*Truck*)*	Truck
L2.	Truck rate per mile for 3S2*	1.10
M2.	Truck highway miles*	2,910
N2.	Truckload per shipment* (same as pounds per shipment)	35,328
O2.	Number of TOFC/COFC(*0*)*	0
P2.	Rail Junction Frequency *	1
Q2.	Observed Rail revenue per hundred weight (cwt) (*1*)*	1
R2.	Rail variable cost per cwt*	3.85
S2.	Rail miles*	2995
T2.	TOFC pickup miles*	7
U2.	TOFC delivery miles*	12

Step 5. Each of the values above should be entered into the respective cell on the TSW sheet to obtain the following output noted on the same sheet beginning with Cell C5. A sample of descriptive outputs will be noted followed by more important outputs that determine diversion. The Cells designating Serial Number, STCC, Ostate, Dstate, Origin FIPS and Destination FIPS are descriptors in the Output Cells and are used in post processing to group and analyze data according to geography or perhaps commodity.

CELL	FIELD NAME	VALUE
C5.	Serial Number	1
D5.	STCC	20
E5.	Ostate	NJ
F5.	Dstate	WA
Z5.	Origin FIPS	34
AA5.	Destination FIPS	53

Step 6. Review the output for the Cells designating Chosen Mode (Cell J5) and Transportation and Logistics Costs (Cell AF5 and Cell AG5 contain the total annual logistics cost for rail and truck, respectively). Since this is the base case that uses a sample record, the setting of the model's parameters should result in the selected mode being the same as the observed mode, the 5-axle tractor or 3S2, here designated in Cell J5 as "2." This corresponds with Cells on the TSW sheet F21 and H21. If the Chosen Mode was rail intermodal, then Cell J5 would contain a "1," and H21 would also contain a "1." The Output line also contains a number of summary statistics such as total miles for both truck and rail and the number of shipments per year. In addition, these results show transportation and other logistics cost for each of the respective modes in Cells noted below.   A comparison of logistics costs per year are the determining factor for which mode wins the business. However, there are caveats or conditions that must be met.

CELL	FIELD NAME	VALUE
J5.	Chosen Mode	2
R5.	Number of Shipments	28
AF5.	Total Annual Rail Logistics Costs	$91,069.91
AG5.	Total Annual Truck Logistics Costs	$93,647.73

Note that the Total Annual Rail Intermodal Logistics Cost (Cell E57) is less than the Total Annual Truck Logistics Cost (Cell F57) but the Chosen Mode is 2, the tractor-trailer. For truck to divert to rail, a shipper/receiver had to reach a hurdle in saved logistics costs. The model currently is set

at 3 percent (See Assumptions Sheet Cell D6) of Total Annual Truck Logistics cost or $20 thousand—whichever is less. (See Assumptions Sheet Cell D7 formula.) This approach was taken to avoid instances where diversion would occur if rail logistics were 1 cent below truck logistics costs but still offering a realistic hurdle on savings. The user can change these parameters as needed.

Scenario Run:

Suppose that for the corridor from New Jersey to Washington, rail is offering service improvements that will increase rail speed by 3 miles per hour from 30 mph to 33 mph (See Assumptions Sheet Cell D11) and will improve reliability from 0.45 to 0.43 (See Assumptions Sheet Cell L8), closer to truck, which is at 0.40 (Assumptions Sheet Cell M8). In addition, since this move goes from the east coast to the west coast, an interchange to another railroad must occur. The model is currently set at 1.5 days (See Assumptions Sheet Cell C25) to accomplish this interchange, but assume in the analysis that improvements in rail operations now accomplish the interchange in 0.75 days.

Step 1. From the description of rail service improvements noted above, change on Assumptions Sheet Cell D11 to 33 from 30. On same sheet, change Cell L8 to 0.43 from 0.45. And on same sheet, change the value in Cell C25 to 0.75 from 1.5.

Step 2. By changing the respective fields, the calculations flow through the spreadsheet. At this point the user need only read the results. On the TSW sheet, observe the changes in output—Row 5. Now the mode that moves the freight is rail intermodal, designated by "1" in the Chosen Mode field. Here, rail service improvements met the 3 percent hurdle for shipper/receiver savings.

CELL	FIELD NAME	VALUE
J5.	Chosen Mode	1
S5.	Number of Shipments	28
AF5.	Total Annual Rail Logistics Costs	$90,704.41
AG5.	Total Annual Truck Logistics Costs	$93,647.73

Example 2.   Operating Macro for Processing Truck Flow Data In Excel Workbook *truck itic input.xls*

Step 1. In this example, the user will employ the macros on the sheet "Running Macros." Details of each macro's operation are contained within the colored box. Here the blue box or the macro titled "Truck-to-Rail Intermodal Base Case" will be used. The data used in this macro resides in an Excel workbook called *truck itic inputl.xls* and has been provided as a sample data set. **Remember to change the parameters back to their original settings prior to running the base case. This can be done by selecting the green macro box "reset defaults."**

Step 2. Click on the Base Case button in the box. If the data file is not open, a message will appear stating that. The file must be open prior to running the macro. The data in this file is contained in "Sheet1" and contains 124 records, which have been selected specifically to illustrate several ways that the model handles the truck-to-rail intermodal decision process. After opening the file, return to the "Running Macros" sheet and click "Base Case" again. A message should appear stating "124 records processed with 107 records available for policy analysis." Click "ok." These records are written to "Sheet2" in the open data file and are ready for processing.

"Sheet3" contains the results of the 124 records from the Base Case Run. A quick review of this sheet will show that 10 records were not accepted for review because they had 110 percent of rail variable cost plus dray cost greater than the calculated rail rate. Under the model's logic a railroad will not carry the traffic at a rate below cost. Each record that met this criterion has an "x" under the column heading "flag for rail rate less than cost" (or column AF). Further review will show that 7 records were not accepted for review because the model assigned them to rail intermodal. Looking under the column with heading "chosen mode" (or column H) and

locating those with "1" will quickly identify those records. Further analysis will show that rail logistics costs met the 3 percent or $20 thousand threshold noted above. Each of these records is characterized as mis-assigned. In all, 17 records were rejected for the policy run.

Step 3. Suppose as in the prior example, rail is offering service improvements that will increase rail speed by 3 miles per hour from 30 mph to 33 mph (See "Assumptions" sheet Cell D11) and will improve reliability from 0.45 (See Assumptions Sheet Cell L8) to 0.43, closer to truck which is at 0.40 (Assumptions Sheet Cell L9). In addition, for those moves that experience a rail junction for their east coast to west coast travel, an interchange to another railroad must occur, so noted on the data set by the column heading junction (See column P "junction frequency" Sheet1 and Sheet 2 of data set). The model is currently set at 1.5 days (See "Assumptions" sheet Cell K33) to accomplish this interchange but under the analysis, consider improvements in rail operations that now accomplish the interchange in 0.75 days. Change each of these parameters as those noted in the previous example.

Step 4. Once completed return to the "Running Macros" sheet and click on the "Policy Case" button. A message should appear stating that 107 records were processed with 6 diverted to rail intermodal. After clicking "ok," a second message appears, telling the user to see sheet "Sheet4" of the data file *truck itic input.xls* for details. The user is also instructed to review the "Output Summary Statistics" provided on the "Running Macros" sheet From the summary statistics the user can see the amount of traffic that remained on truck and the amount of traffic that diverted to rail intermodal. For much more detail, the user can analyze the "Policy Output" sheet by first observing that the "Chosen Mode" column (Column H) has the value "2" in six rows noting that rail intermodal was the low cost mode and those moves that were previously on truck now go by rail. The number "3" in the cells in column H notes those moves remaining on truck. This sheet contains a number of different logistics costs statistics as well as other data available for the user to analyze.

For a complete comparison of changes in the base and policy case for those moves that diverted, the user is encourage to analyze the detailed statistics for the appropriate records on "Sheet3" and "Sheet4" of the data file.

Step 5. To reset the parameters, the user can simply click on the button "Reset Defaults" in the green box.